

Estimating Winds and Waves From SAR Under Typhoon Conditions

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LONG-TERM GOALS

The long-term goal of this program is to be able to utilize SAR imagery to improve predictions of storm tracks and storm strength at landfall (we use storms as stand-in for hurricanes, typhoons, etc.). This will be done with a system that uses SAR imagery of the storm at sea to estimate wind and wave conditions within the storm, then utilizes these estimates to re-set storm model parameters so that the predicted winds/waves at the time of the SAR imagery match the actual winds/waves. The goal is that the model predictions derived with the re-set parameters will be improved over those that do not have the SAR estimates.

OBJECTIVES

There are three objectives in this program.

- (1) Modify the existing General Dynamics Advanced Information Systems (GDAIS) wind vector tool to handle the higher wind states in storms and generate accurate maps of wind vectors within the storm.
- (2) Modify the existing GDAIS wave spectra tool to handle the higher wind/wave states of storms and generate accurate maps of wave height statistics within the storm.
- (2) Work with storm modelers to determine the best approach for incorporating the SAR-derived wind and wave information into the model predictions.

APPROACH

(1) Modification of the wind vector tool

Under the NOAA/NESDIS funded Alaska SAR Demonstration Project, GDAIS has developed an algorithm for estimating wind vectors from SAR imagery (Wackerman et al., 2003). Wind directions come from a projection-based method to find linear features in the SAR image that are aligned with the wind. Wind speed comes from inverting a physics-based forward model for the RCS that uses the two-scale model to predict mean RCS values (Wackerman et al., 2002). The forward RCS model already has a tilted Bragg scattering term (so there is no linearization of the tilted ocean surfaces), a hydrodynamic modulation term that induces an upwind, downwind asymmetry as seen in observations, a spectral scattering term for wave facets tilted toward the radar, and a choice of possible wave spectral models to use. This model has already been validated for C-VV and C-HH data (Wackerman et al., 2002) and is currently being validated for X-band VV and HH data as part of a set of airborne SAR

collections. First we propose putting into this forward RCS model a wave height modulation model appropriate for typhoon conditions; i.e. a model where the wave heights grow appropriately with the strong winds. Second, we currently assume a zero-mean Gaussian distribution for the wave facet tilts where the standard deviation is modeled based on wind speed. The model for slope variance with respect to wind will need to change for typhoon conditions, and we will need to examine whether the Gaussian assumption is still correct (essentially whether the waves are dominantly non-linear). Theoretically the rest of the forward model should work as is. We will compare the resulting forward RCS model with CMOD4 and CMOD5, as well as validate it against the test set discussed below (note that we can validate the forward RCS model separate from validating the wind or wave tools).

The wind direction estimation will most probably also need to be modified to handle the smaller spatial scale of significant changes in wind direction for typhoon conditions. Currently the projection code assumes a relatively large spatial scale (~16km) for wind direction changes. We anticipate that this will be performed by changing the metric used to determine which projection has the largest variation across spatial scales (and thus represent the direction that is orthogonal to the wind vector). Currently this is done by finding the direction of maximum contrast (standard deviation divided by the mean). We may not have enough samples to generate accurate statistics over the short spatial scales, so we anticipate needing a metric based on more point-line measurements (e.g. maximum minus minimum value, or the maximum local gradient).

(2) Modification of the wave spectra tool

Also under NOAA/NESDIS funding, GDAIS has developed an automated wave spectrum estimation tool based on both linear transfer function (Wackerman, 2006) as well as a fully non-linear transfer function that iteratively finds the underlying wave spectrum from a starting assumption of no waves (thus no a priori wave information is required). We anticipate needing the fully non-linear transfer function for typhoon conditions. However this forward model has an internal wave-to-RCS transfer function that is probably not appropriate for typhoon conditions. We proposed modifying this by incorporating the forward RCS model from the wind vector tool into the wave estimation tool to allow accurate RCS modulations from typhoon-condition waves. All the non-linearity of the SAR imaging process should then work as currently implemented. This will require modifying the iteration process which uses a gradient estimate to perform a conjugate gradient search for the wave spectra that minimizes errors with the SAR image. We will need to re-derive this gradient using the new forward RCS model.

(3) Implementation into models

Working with modelers we will determine how to best utilize the SAR-derived wind and wave maps into their models. Most probably this will be done by determining the model parameters that can reconstruct the SAR-derived winds/waves for the time of the image, then using these new parameters to perform model predictions.

REFERENCES

Wackerman, C.C., Clemente-Colón, P., Pichel, W.G., Li, X. A Two-Scale Model To Predict C-Band VV and HH Normalized Radar Cross Section Values Over the Ocean, Can. J. Remote Sensing, vol. 28, 367-384, 2002.

Wackerman, C.C., W.G. Pichel, P. Clemente-Colon," A projection method for automatic estimation of wind vectors with RADARSAT SAR imagery," Proc. 2nd Workshop on Coastal and Marine Applications of SAR, Svalbard, Norway, 2003 (ESA SP-565).

Wackerman, C., "Estimating wave height spectra from SAR imagery," General Dynamics AIS Final report, January 5, 2006.

WORK COMPLETED

Funding for this program only arrived late in FY '08. No significant technical work has begun yet. Kick-off meetings were attended in both Taiwan and Florida over the past year.

RESULTS

Funding for this program only arrived late in FY '08. No technical results have been generated yet.

IMPACT/APPLICATIONS

If successful, the resulting system may significantly improved predictions of storm tracks and storm strength at landfall. This would have a large impact on coastal regions.

RELATED PROJECTS

There are no ongoing related projects that are closely identified with this project.